Chapter 5: Health and Safety

This chapter addresses some of the most pressing hazards that households face, as well as those faced at work by weatherization professionals. When serious safety problems are discovered in a home, field staff should inform an immediate supervisor and the occupants about the hazards. Major hazards and potentially life-threatening conditions should be corrected before weatherization installers begin work in the dwelling, unless the installers are making the corrections as part of their work.

See *Health and Safety Inspection Check List* and the *Release of Liability Form* located via link on the Home Energy Plus website linked below:
http://homeenergyplus.wi.gov/category.asp?linkcatid=494&linkid=122&locid=25

5.1 Personal Protective Equipment

On almost a daily basis, weatherization workers find themselves in situations that necessitate the use of personal protective equipment (PPE). The weatherization agency is required to provide workers with PPE needed to complete their jobs.

Examples of such PPE include, but are not limited to:

- ✓ Disposable coverall garments
- ✓ NIOSH-approved respirators
- ✓ Eye and face protection
- ✓ Confined-space supplied air and ventilation
- ✓ Hearing protection

5.2 Materials Safety Data Sheet (MSDS)

MSDS contain data about material specifications and safety information. This data includes information about:

1. Product and company/manufacturer
2. Hazards identification
3. Composition and ingredients
4. First-aid
5. Firefighting
6. Accidental release
7. Handling and storage
8. Exposure controls and personal protection
9. Physical and chemical properties
10. Chemical stability and reactivity
11. Toxicological effects
12. Ecological information
13. Disposal
14. Transport considerations
15. Regulatory information
16. Other

All MSDS for weatherization products can be accessed through the Home Energy Plus Training and Technical Assistance website.

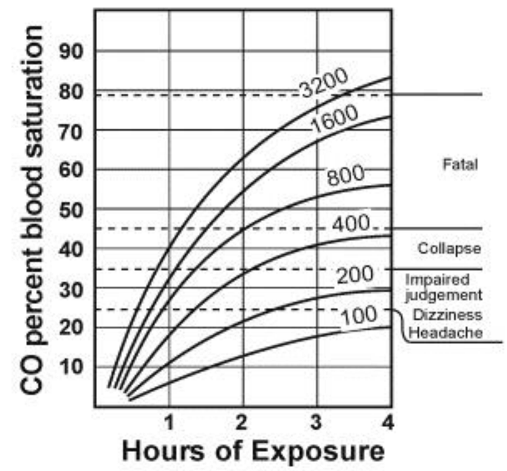
5.3 Source Pollutant Control

The control of pollutants at the source is always the best solution, especially in tighter homes. Whole building mechanical ventilation will help remove and dilute low levels of pollutants. Technicians should be mindful of pollutants while performing weatherization.

The occupants have control over the introduction and spread of many home pollutants. Always educate residents about corrective actions or lifestyle changes that would minimize pollutants in their homes.

5.3.1 Carbon Monoxide (CO)

The EPA's suggested maximum 8-hour exposure limit for CO is 9 parts per million (ppm) in room air. CO at or above 9 ppm is often linked to malfunctioning combustion appliances within the living space. Technicians are encouraged to wear personal CO monitors while performing combustion safety testing.



Effects of CO: This graph's 6 curves represent different exposure levels in parts per million.

Sources of Carbon Monoxide

CO is often linked to unvented combustion appliances, back-drafting combustion appliances, gas ranges, charcoal grills, and motor vehicles idling in attached garages or near the home.

Testing for Carbon Monoxide

The most common CO testing instrument is an electronic sensor with a digital readout in parts per million (ppm). The readings will be either *AS MEASURED* or *AIR FREE.* Follow the manufacturer's recommendations on zeroing the meter — usually by exposing the meter to clean air. CO testing equipment requires recalibration about every 6 months, using factory-specified procedures.

A CO test is normally completed in the exhaust flue or at the exhaust port of the heat exchanger. Elevated CO can be caused by any of the following:

1. Over firing of an appliance — this occurs when too much combustion fuel is supplied to the appliance. A low O_2 percentage on a combustion analyzer indicates that the appliance may be over firing. Technicians determine if the appliance is over firing by clocking the gas meter.
2. Inadequate combustion air — this occurs when a combustion appliance is starved for combustion air.
3. Back-drafting of combustion gases suppressing the flame.
4. Flame interference by an object (a pan over a gas burner on a range top, for example).
5. Misalignment of the burner.

Appliance service technicians should strive to identify and correct these problems.

5.3.2 Gas Range and Oven Safety

Testing Range-Top Burners

Test ranges prior to testing ovens for carbon-monoxide levels. Range-top burners must be tested as measured (in ambient air without adjustment for oxygen content). To test range-top burners:

1. Remove all pots and foil from the burner area.
2. Turn each range-top burner on high and allow to warm
3. Position the testing probe 6 inches above the flame.

Table 5-1: Action Levels for Range Top Burners

As Measures CO PPM	Measuring Time	Action
< 25 PPM	3 minutes of operation	Should be cleaned by client to prevent possible CO problems.
25 to 50 PPM	3 minutes of operation	Have appliance serviced
>50 PPM	3 minutes of operation	Appliance should not be used until either repaired or replaced.

Testing Gas Ovens

When completing oven testing:

1. Test ovens for air free carbon monoxide levels.
2. Remove any items stored in the oven and any foil coverings, before turning the oven on.
3. Verify that self-cleaning features are deactivated.
4. Insert the testing probe into the vent sleeve, pre-dilution-air.
5. Turn the oven on to its highest temperature setting, and allow the oven to run for 10 minutes continuously.
6. Measure the oven during warm-up, and record the measurement at peak (after 10 minutes of run-time). Confirm that the oven is indeed firing when the measurements are taken.
7. Test the ambient air to verify that the CO level is acceptable.

Table 5-2: Action Levels for Range Ovens

Air Free CO PPM	Measuring Time	Action
< 800 PPM	After 10 minutes	Should be cleaned by client to prevent possible CO problems.
> 800 PPM, <1000 PPM	After 10 minutes	Have appliance serviced
>1000 PPM	After 10 minutes	Oven should not be used. Replace appliance.

5.3.3 Carbon Monoxide (CO) Alarms

Follow these instructions when installing CO alarms:

1. Educate the occupants about the purpose and features of the alarms, and about what to do if an alarm sounds.
2. Leave instructions with the customer, and educate the customer about battery replacement.

Do not install CO alarms:

1. In a room that may get too hot or cold for the alarm to function properly.
2. Within 5 feet of a combustion appliance, vent, or chimney.

3. Within 5 feet of a storage area for vapor-producing chemicals.
4. Within 12 inches of exterior doors and windows.
5. Inside of a furnace closet or room.
6. With an electrical connection to a switched circuit.
7. With a connection to a ground-fault interrupter circuit (GFCI).
8. Behind furniture or appliances.

The manufacturer’s instructions may specify stricter standards than these. If a conflict exists, follow the stricter specification.

5.3.4 Smoke Alarms

Follow these instructions when installing smoke alarms:

1. Install according to the manufacturer’s instructions.
2. Install one smoke alarm on the floor where the wood heater is located; and another in the sleeping area, if the sleeping area is located on a separate floor.
3. If mounted on a wall, mount from 4 to 12 inches from the ceiling.
4. If mounted on a ceiling, mount at least 6 inches from the nearest wall.

Do not install smoke alarms:

1. Within 12 inches of exterior doors and windows.
2. On a switched circuit, if hard-wired.
3. On a ground-fault interrupter circuit (GFCI).

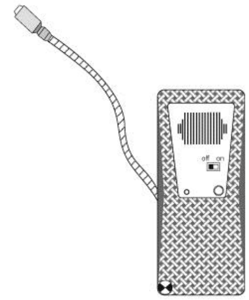
The manufacturer’s instructions may specify stricter standards than these. If a conflict exists, follow the stricter specification.

5.3.5 Leak-Testing Gas Piping

Natural-gas and LP piping systems may leak at their joints and valves. Find gas leaks with an electronic combustible-gas detector, often called a gas sniffer. A gas sniffer will find all significant gas leaks, if used carefully. Remember that natural gas rises from a leak and propane falls, so position the sensor accordingly.

Test for gas leaks by following these steps:

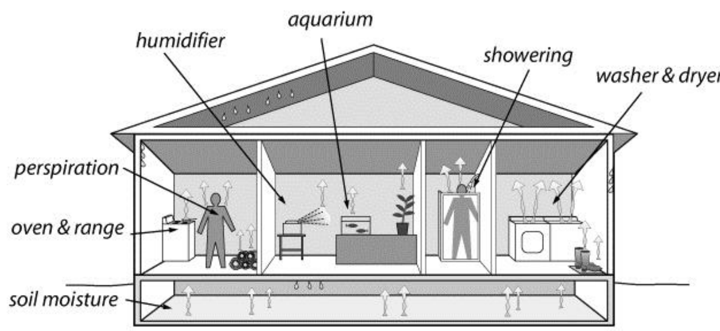
1. Sniff all valves and joints in the gas system with the gas sniffer. Include connections to all gas appliances and gas stove valves. No gas leaks are allowed in the building.
2. If the sniffer detects a leak, verify the leak with a non-corrosive bubbling liquid designed for finding gas leaks.
3. Repair all gas leaks verified with bubbling liquid.
4. Replace kinked or corroded flexible gas connectors.



Gas sniffer: These electronic combustible-gas detectors are a fast and convenient way to find gas leaks.

5.3.6 Moisture Problems

Moisture causes billions of dollars' worth of property damage and high energy bills each year in American homes. Water damages building materials by dissolving glues and mortar, corroding metal, and nurturing pests like termites, and dust mites. These pests, in turn, cause many cases of respiratory distress.



Moisture sources: Household moisture can often be controlled at the source by informed and motivated occupants. Indoor relative humidity should be between 30% and 50%.

Water reduces the thermal resistance of insulation and other building materials. The most common sources of moisture are leaky roofs and damp foundations. Other critical moisture sources include dryers venting indoors, showers, cooking appliances, and unvented gas appliances like ranges or decorative fireplaces.

Table 5-3: Moisture sources and their potential contributions

Moisture Source	Potential Amount Pints
Ground Moisture	0-105 per day
Seasonal evaporation from materials	6-19 per day
Dryers venting indoors	4-6 per load
Dishwashing	1-2 per day
Cooking (meals for four)	2-4 per day
Showering	0.5 per shower

Reducing sources of moisture is the first priority for solving moisture problems. Next most important are air and vapor barriers to prevent water vapor from migrating through building cavities. Relatively airtight homes may need whole building mechanical ventilation to dilute accumulating water vapor. Local exhaust fans located in the kitchen and bathrooms will remove bulk moisture and other pollutants at the source.

Relative humidity is a measurement of the percent that air is saturated with moisture. Air at 100% relative humidity (rh) is saturated. Air below 30% rh is uncomfortably dry for many people. Air above 50% rh is a threat to cause condensation on cold interior surfaces and in building cavities during winter.

Symptoms of Moisture Problems

Condensation on windows, walls, and other surfaces may signal high relative humidity and the need to find and reduce moisture sources. During very cold weather or rapid weather changes, condensation may occur. This occasional condensation isn't a major problem. However, if window condensation is a persistent problem, reduce moisture sources, add insulation, or consider other remedies that lead to warmer interior surfaces. The colder the outdoor temperature, the more likely condensation is to occur. Adding insulation helps eliminate cold areas where water vapor condenses.

Moisture problems arise when the moisture content of building materials reaches a threshold that allows pests like termites, dust mites, rot, and fungus to thrive. Asthma, bronchitis and other respiratory ailments can be exacerbated by moisture problems because mold, mildew, and dust mites are potent allergens. The level of moisture problem can be determined by the current state of the existing building materials. The following are examples how moisture affects building materials:

1. Rot and wood decay indicate advanced moisture damage. Unlike surface mold and mildew, wood decay fungi penetrate, soften, and weaken wood.
2. Peeling, blistering or cracking paint may indicate that moisture is moving through a wall, damaging the paint and possibly the building materials underneath.
3. Corrosion, oxidation and rust on metal are unmistakable signs that moisture is at work. Deformed wooden surfaces may appear as damp wood swells and then warps and cracks as it dries.
4. Concrete and masonry efflorescence often indicates excess moisture at the home's foundation. Efflorescence is a white, crystalline deposit left by water that moves through masonry and leaves minerals from mortar or the soil behind as it evaporates.

5.3.7 Crawl-Space Moisture Control

A surprising number of moisture problems in the home are caused by ground moisture sources. Moisture that enters the home through foundations and crawl spaces can be a substantial contributor to indoor humidity even when no wet areas are apparent. This moisture will move easily through the home, driven by stack effect and by wicking into permeable wood and concrete.

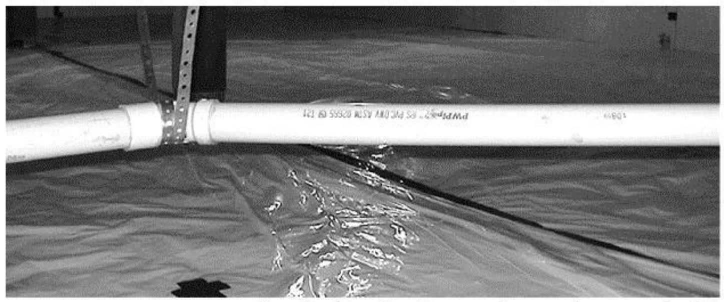
Crawl-Space Ventilation

Install crawl-space ventilation when the floor has been insulated Follow the code guidance for the installation of ventilation.

Ground-Moisture Barriers

Air, moisture, and pollutants can move through soil and into crawl spaces and dirt-floor basements. Even soil that seems dry at the surface can release a lot of moisture into the home.

Follow these instructions when installing a ground-moisture barrier to control the movement of moisture and soil gases:



A well sealed crawl space: The dirt floor in this crawl space is covered with a well-sealed cross-linked polyethylene ground moisture barrier.

1. Cover the ground completely with an airtight barrier, such as 6-mil plastic or cross-laminated polyethylene.
2. Run the barrier up the foundation wall at least 6 inches, or attach it to the mud sill if termites aren't a problem in the area.
3. Seal the edges and seams with adhesive to create an airtight seal. It may be easier first to assemble and seal the barrier outside of the crawl space. When the sealing compound sets up, the barrier should be a continuous sheet.

Caution: Moisture barriers are typically for use in crawl spaces. Use in basements should be limited to basements with dirt floors and limited access. When the ground-moisture barrier is installed in a little-used basement, install walk boards to prevent residents from slipping. Address any problems, such as plumbing leaks, prior to installing the barrier, to prevent water from pooling on top of the barrier.

5.3.8 Lead and Lead-Safe Weatherization

Lead dust can damage the neurological systems of persons who ingest it. Children are more vulnerable than adults because of their common hand-to-mouth behavior. Lead paint commonly was used in homes built before it was outlawed in 1978. Technicians working on these older homes should either assume the presence of lead paint; or, if they believe no lead paint is present, perform tests to rule out its presence.

Lead-safe weatherization (LSW) is a group of work practices used by weatherization professionals when they suspect or confirm the presence of lead paint. LSW focuses on rigorous dust-prevention and housekeeping precautions. LSW is required when workers will disturb painted surfaces by cutting, scraping, drilling, or other dust-creating activities. Workers must be trained in LSW practices.

Lead Safe Renovator requirements apply in pre-1978 housing when more than 6 square feet of interior painted surface per room or more than 20 square feet of exterior painted surface will be disturbed, or when windows will be replaced or demolished. See the Wisconsin Weatherization Program Manual, Appendix G, for specific policies and guidance regarding Lead Safe Renovator requirements and minimum standards for lead-safe weatherization.

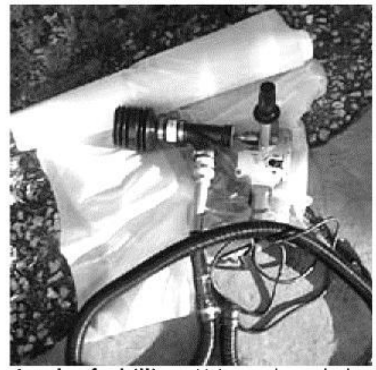
Weatherization activities that could disturb lead paint and create lead dust include, but are not limited to, the following:

1. Glazing, weather-stripping, or replacing windows.
2. Weather-stripping, repairing, or replacing doors.
3. Drilling holes in the interior of the home for installing insulation.
4. Removing trim or cutting through walls or ceilings.
5. Removing siding for installing insulation.

Wall-blowing tent: This tent protects occupants and their belongings from insulation and paint dust.

When engaging in the above activities, take the following precautions:

1. Tent off the work area by taping a continuous sheet of plastic from floor to ceiling.
2. To protect installers from breathing dust, use appropriate personal protective equipment, such as fit-tested respirators, coveralls, etc.
3. Confine the work area within the home to the smallest-possible floor area. Seal this area off carefully with floor-to-ceiling barriers made of disposable plastic sheeting, sealed at floor and ceiling with zip poles or tape.
4. Cover furniture and carpet in the work area with disposable plastic sheeting.
5. Spray water on the painted surfaces to keep dust out of the air during drilling, cutting, or scraping painted surfaces.
6. Use a dust-containment system with a HEPA vacuum when drilling holes indoors.


Lead-safe drilling: Using a shrouded drill with a HEPA vac removes dust where it is generated.

7. Clean up as work is performed. Vacuum affected areas with a HEPA vacuum and wet-mop these surfaces daily. Don’t use the occupant’s cleaning tools or leave the occupant with lead dust to clean up.
8. Avoid taking lead dust home on clothing, shoes, or tools. Wear boot covers while in the work area, and remove them to avoid tracking debris from the work area to other parts of the house. Wear disposable coveralls, or vacuum cloth coveralls with a HEPA vacuum before leaving the work area.
9. Wash thoroughly before eating, drinking, or quitting for the day.
10. Keep children and pets away from the work area.

For more information, refer to the DOE publication *Lead Safe Weatherization, A Training Manual for Weatherization Managers and Crews*.

5.3.9 Asbestos

Asbestos fibers are not visible to the naked eye. Nevertheless, exposure to asbestos can lead to a host of health problems — including, but not limited to:

1. Lung cancer
2. Mesothelioma, a rare form of cancer that is found in the thin lining of the lung, chest and the abdomen and heart
3. Asbestosis, a serious progressive, long-term, non-cancer disease of the lungs

Disease symptoms may take many years, or decades, to develop after exposure to asbestos. Being a smoker greatly increases the odds that exposure to asbestos will lead to disease.

According to Wisconsin Department of Health Services, workers may assume that asbestos is not present in wood, metal, glass, and fiberglass. All other building materials, however, should be presumed to contain asbestos, unless proven otherwise through bulk sampling by a certified Asbestos Inspector and analysis by an accredited laboratory.

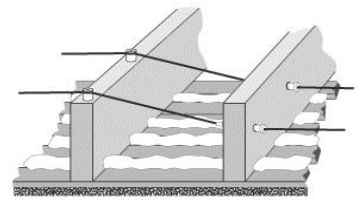
Vermiculite is the one exception — currently, there is no EPA-approved testing method to demonstrate the presence or absence of asbestos mixed in with vermiculite insulation. Consequently, weatherization workers must presume that asbestos is mixed in with all vermiculite insulation.

See the Wisconsin Weatherization Program Manual, Appendix H, for comprehensive asbestos policies.

5.4 Electrical Safety

Follow these steps for electrical safety in existing homes:

1. Confirm that attics contain no exposed wiring. Confirm that wire splices in attics are enclosed in metal or plastic electrical boxes with cover plates.
2. Install covers on open junction boxes in the attic.
3. Mark all junction boxes in the attic that will be concealed by insulation, with flags.
4. Don't insulate wall cavities containing live knob-and-tube wiring. Eliminate live knob-and-tube wiring whenever possible.



Knob-and-tube wiring: Prior to insulating around knob-and-tube wiring, barriers must be installed to keep insulation at least 3 inches from the wires.

5. Isolate live knob-and-tube wiring in attics by building a barricade around it. There are several materials that work well as barricades: R-30 unfaced fiberglass batts is one readily available product; concrete-form tube (Sonotube®), made out of either cardboard or plastic, may be cut and slipped over the wiring. Keep the barricade materials at least 3 inches away from the live knob-and-tube wiring. Note: Before installing a barrier, verify that the wiring is live.
6. Inspect wiring, fuses, and circuit breakers to confirm that wiring is not overloaded. Install S-type fuses where appropriate to prevent circuit overloading. Maximum fuse or breaker amperage for 14-gauge wire is 15 amps and for 12-gauge wire is 20 amps.

S-type fuse: An S-type fuse prohibits residents from oversizing the fuse and overloading an electrical circuit.

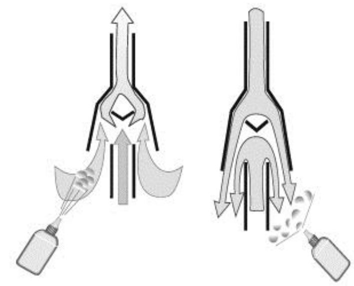
7. Install junction box covers where missing if an imminent hazard exists for workers or occupant.
8. Install GFCI receptacles in accordance with National Electrical Code (NEC) 210.8.

5.5 Worst-Case Draft Protocol

The main purpose of measuring draft is to confirm that the combustion gases will vent safely out of a home. Draft is also an indicator of the effectiveness of the venting system and the stability of the combustion process. Draft is measured in inches of water column (in. w.c.) or pascals (Pa).

5.5.1 Measuring Draft

Many combustion appliances exhaust their gases into a natural-draft chimney. A natural-draft chimney produces negative draft — a partial vacuum. The strength of this draft is determined by the chimney's height, its cross-sectional area, and the temperature difference between the flue gases and outdoor air. Natural draft up a chimney should always be negative. A positive draft reading indicates that the flue gases are spilling into the ***combustion-appliance zone (CAZ)***. A combustion-appliance zone is an area containing one or more combustion appliances.



Negative versus positive draft: With positive draft air flows down the chimney and out the draft diverter. A smoke bottle helps distinguish between positive and negative draft in atmospheric chimneys.

Natural-draft chimneys transport combustion gases using the flame's heat and the gases' buoyancy. Natural-draft gas appliances are designed to operate at a chimney draft of around negative 0.02 in. w.c., or –5 Pa. Tall chimneys located indoors typically produce stronger drafts, and short chimneys or outdoor chimneys produce weaker drafts. Wind and house pressures have a big impact on natural-draft chimneys.

Fan-assisted appliances employ a small fan near the exhaust of their heat exchanger. This fan regulates the over-fire draft, but it has little or no effect on the draft up the chimneys. Positive-draft appliances, like condensing furnaces, have a strong positive draft and an airtight venting system. The positive draft of these appliances is created by an inducer fan and is strong enough to resist the influence of most indoor and outdoor pressures. It is critical that the venting system of a positive-draft appliance be airtight — otherwise, the positive pressure inside the system will force exhaust gases into the living space.

Table 5-4: Acceptable Draft Test Readings for Gas Appliances

	Outdoor Temperature (Degrees F)				
F°	<20	21-40	41-60	61-80	>80
Pas-cals	-5	-4	-3	-2	-1
IWC	-.02	-.016	-.012	-.008	-.004

Table 5.5 – Acceptable Draft Test Readings for Oil-Fired Appliances

Test Location	Acceptable Draft
Overfire Draft	-0.02 IWC or -5 pascals
Flue Drafts	-0.04 to -0.06 or -10 to -15 pascals

5.5.2 Depressurization Testing and Worst-Case Draft Testing

Depressurization is the leading cause of back-drafting and flame roll-out. Depressurization testing uses the home's exhaust fans, air handler, and chimneys to create worst-case depressurization in the CAZ. During this worst-case testing, the chimney draft and the indoor-to-outdoor pressure differential will be measured.

CAZ Depressurization Test

This test measures the conditions of the building and the CAZ, both before and after weatherization work. The test also helps to determine the measures needed for the safe operation of combustion appliances in the building. Such measures might include duct sealing or modifying a forced-air distribution system. Use the electronic Diagnostic Workbook, to document the test results.

Before the test, run a pressure hose to the outdoors. Then, put the dwelling in "winter condition" — close all backdraft dampers, windows, and exterior doors (without crushing the pressure hose). Finally, open all interior doors, and close the doors to the CAZ.

Connect the pressure hose to the Input tap of the digital manometer, on "PR/PR" mode. The test may be started in one of two ways:

A) ***Use the Automatic Baseline Feature of the Digital Pressure Gauge*** — press the Baseline button on the digital pressure gauge, and then press the Start button. On windy days, allow the Baseline function to record for at least 60 seconds. After sufficient time has passed, lock in the Baseline by pressing the Enter button.

B) Manually Record the Baseline Pressure — begin at Step One, below.

Follow these steps to perform the CAZ depressurization test:

1. **Baseline Depressurization**. Measure and record the baseline pressure differential, or Delta P (ΔP), between the CAZ and the outdoors. If the baseline measurement seems unreasonable, check that the pressure hose to the outdoors is not constricted. ***If the automatic Baseline feature of the digital pressure gauge (Method A) is used, skip this step.*
2. **Turn On Exhaust Appliances**. Turn on all of the exhaust appliances in the building, and record the ΔP between the CAZ and the outdoors. A pressure differential that is more negative than the reading from Step One usually indicates that the exhaust fans have depressurized the CAZ.
3. **Turn On the Air Handler**. Turn on the furnace's air handler, and record the ΔP between the CAZ and the outdoors. If the ΔP has become more negative than in Step

Two, it usually means the return ducts have depressurized the CAZ. By contrast, a more-positive ΔP usually means that supply ducts are pressurizing the CAZ. Determine distribution sealing needs based on this reading and other diagnostic tests (when needed). Use the electronic Diagnostic Workbook to guide duct sealing.

4. **Position Interior Doors**. Use the digital gauge to measure the relative pressure of each room. Connect a hose to the Input tap, toss the hose into the room, and close the door without pinching the hose. If the reading is negative, open the door. If the reading is positive or neutral, close the door. Return to the basement and record the ΔP between the CAZ and the outdoors. If the reading is more negative than during Step Three, it may mean there are not enough return ducts in the living area. Determine distribution modifications based on this reading and other diagnostic tests.

Table 5-6: Maximum Depressurization for Combustion Appliance Zones

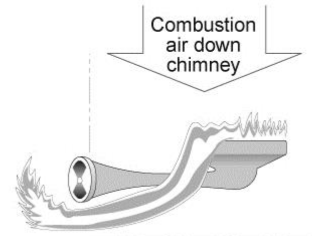
Appliance Type	Maximum Depressurization
Natural Draft Water Heater	-2
Natural Draft Heating System or Stove	-5
Natural Draft Water Heater and Heating System	-3
Natural Draft Water Heater and Induced Draft Heating System	-5
Induced Draft Heating System	-15
Power Vented Water Heater and Seal-Combustion Furnace	-25
Based on information from the Minneapolis Center for Energy and the Environment and The Energy Conservatory	

5. **Open the Door to the CAZ**. Open the door to the CAZ, and record the ΔP between the CAZ and the outdoors. If the pressure difference is more negative than in Step Four, it may mean the exhaust fans are depressurizing the CAZ.
6. **Worst-Case Depressurization**. Subtract the Baseline reading from the largest negative reading (or the smallest positive), to get the adjusted Worst-Case Depressurization. ***The Diagnostic Workbook will complete this step automatically.***

When results are entered into the electronic workbook, the workbook will “flip the signs”. For example, if a pressure of -3.8 is entered, the workbook will display “+3.8”.

Worst-Case Draft Test

Worst-case conditions do occur, and chimneys must vent their combustion gases even under these extreme conditions. Worst-case draft testing will discover whether or not the venting system will exhaust the combustion gases when the combustion-zone pressure is at its worst case. A calibrated digital pressure gauge is essential for accurate and reliable readings of both combustion-zone depressurization and chimney draft.



Flame roll-out: Flame roll-out, a serious fire hazard, can occur when the chimney is blocked, the combustion zone is depressurized, or during very

Since draft tells us whether combustion gases are being exhausted, we can measure draft and note how it is affected by potential back-drafting causes such as exhaust fans, furnace-blower operation, and opening and closing interior doors.

Follow these steps to perform a worst-case draft test:

1. Set up the house in worst-case-depressurization conditions.
2. Drill an appropriately sized hole in the flue(s) of the appliances to be tested. For gas appliances, drill the test hole in the middle of the flue, halfway between the appliance and the chimney. For oil appliances, drill the test hole before the barometric damper.
3. Fire each combustion appliance, starting with the smallest BTU appliance. Check for spillage of combustion products near the flue diverter, hood or barometric damper. Check for spillage after the appliance has operated for 1 minute.
4. Measure the draft when the appliance has reached steady state operation.
5. Measure CO level in combustion gases. Test for CO in pre-dilution air. For natural-draft heating systems, measure the CO level in each combustion chamber, and record the highest of the measurements. See *Carbon Monoxide in Chapter 5 - Section 5.3.1*.
6. Record results on the electronic Diagnostic Workbook. See *Table 3-2* and *Table 3-5* in Chapter 3 – Section 3.8.3 and Section 3.9.2 for minimum acceptable worst-case draft readings for gas- and oil-fired appliances.
7. If there is not an acceptable draft at worst case, take all reasonable steps to attempt to improve worst-case draft and house depressurization to acceptable levels.

Monitor ambient CO levels during draft testing. An ambient CO level above 20 ppm is a safety hazard – so cease testing immediately. The CAZ should be ventilated before the resumption of draft-testing and diagnosis of CO problems.

5.6 Make-Up Air Systems

Make-up air is only required when the combustion appliance zone is excessively pressurized or depressurized. Use guidelines listed in *Table 5-6 in Depressurization and Worst-Case Draft Testing in Chapter 5* - Section 5.5.2 to determine acceptable pressures.

The Make-Up Air Check worksheet (part of the electronic workbook) helps to determine whether to add make-up air or if the problem can be resolved through other measures. The make-up air is required when the CAZ is excessively depressurized or pressurized. Add make-up air that is 40% of exhaust ventilation. Enter total exhaust air (both continuous and intermittent) in top box. Total exhaust CFM multiplied by 40% (0.40) equals the amount of make-up air required (CFMs).

Make-up air systems provide supply air by way of fans and/or ductwork that introduce outdoor air into the home. These systems are sometimes electrically interlocked with exhaust fans elsewhere in the home so that both fans run at the same time. This protects against the depressurization caused by large exhaust-only fans such as oversize range hoods. Balancing of the two airflows can be performed by way of balancing dampers in the fresh air duct. These systems, if properly balanced, can create house pressures that are closer to neutral than exhaust-only or supply-only systems. Follow the manufacturer's requirements for mixed air temperature and the location of the fresh air inlet.

5.7 Water-Heater Replacement

Occasionally, water heaters must be replaced for health and safety reasons. For information on replacement installation procedures, refer to *Water Heater Replacement in Chapter 4 – Section 4.1*. These reasons may include, but are not limited to:

1. Water heater is back-drafting/spilling. Refer to *Improving Inadequate Draft in Chapter 3 – Section 3.13.1* for guidance on how to remedy these problems.
2. The shell of the storage tank leaks and cannot be repaired.
3. Severe flame roll-out that cannot be repaired.
4. Carbon-monoxide measurement above 100 ppm (as-measured) that cannot be repaired.

5.8 Mechanical Ventilation

Ventilation is an important health-and-safety consideration in most homes that are weatherized in Wisconsin. Many homes have blower-door-measured air tightness and building characteristics that necessitate mechanical ventilation as a means of keeping indoor-air quality at a safe level. For instructions on how to calculate the whole-house ventilation requirement, refer to the “Instructions” tab of the electronic Diagnostic Workbook.

Customers may refuse the installation of the ventilation in their home. Any customer refusing the installation of ventilation must sign the *Refusal of Ventilation: Release of Liability, Indemnification & Waiver of Claims*, available via the link at the beginning of Chapter 5. Refusal of ventilation does not constitute refusal of a major measure. An original copy of the waiver must be given to the customer and a copy retained in the customer’s file.

5.8.1 Choosing Ventilation Systems

Ventilation systems must be matched to the home. A home may require only simple exhaust fans in bathrooms and/or kitchen. Very tight homes may require a balanced central ventilation system.

When ducted ventilation systems are installed in homes with forced-air heating or cooling systems, the ductwork can be shared in a simplified or ducted-exhaust installation. Though this hybrid approach can save some of the initial cost, these systems are more complicated and prone to pressure imbalances. Install fully-ducted systems whenever possible.

In cold climates, heat-recovery ventilators (HRVs) or energy recovery ventilators (ERVs) can offset some of the heat loss from exhausted air. The heat recovery savings will be greatest where winter temperatures are the lowest.

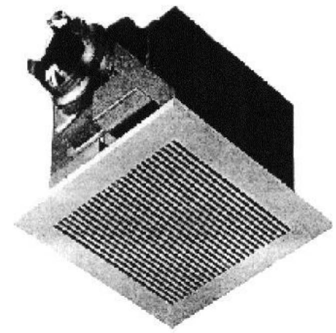
5.8.2 Sizing Ventilation Systems

Ventilation systems are sized according to the size of the home, the number of occupants, or both. Standards that specify ventilation rates in cubic feet per minute (CFM) for each bedroom are based upon the expected occupancy rate. Standards that specify ventilation rates in air changes per hour (ACH) are based upon the volume of the home.

Use the electronic workbook, to determine if ventilation is required. Note: Existing ventilation may be modified to provide either continuous or intermittent ventilation at the required amount, based on the integrity of the existing installation.

5.8.3 Local Exhaust Fans

The ASHRAE 62.2 – 2013 standard for acceptable indoor air quality establishes an on-demand flow rate for local exhaust in bathrooms and kitchens. An optional continuous flow rate is also established by ASHRAE 62.2 – 2013. An alternate compliance path that increases the flow rate of whole building ventilation to offset the lack of local exhaust is available for existing homes.



Surface-mounted exhaust fan: Always buy the best fans available to ensure quiet, efficient, and long-lived operation.

Follow these instructions when installing local exhaust fans to remove bulk pollutants and moisture:

1. Locate exhaust fans as close to the source(s) of pollutants/moisture as possible. For example, install bath fans as close to the shower as practical, and install kitchen fans near the range.
2. Install exhaust fans as close as possible to the heated space, which usually means against the ceiling surface.
3. Consider the positioning of the new fan's exhaust port. Position ceiling fans so that the exhaust port runs parallel with the ceiling joists and points toward the existing exhaust termination. If no existing termination is present, best practice is usually to point the fan's exhaust port toward the center of the attic. This makes it easier to attach exhaust ducting.
4. Avoid installing fans in vaulted ceilings, walls, or slopes if possible. These installations displace insulation and encourage cold spots, which foster condensation. Also, these installations make it difficult to duct the fan to the outdoors.

5.8.4 Whole Building Exhaust Only Ventilation

The ASHRAE 62.2 – 2013 standard for acceptable indoor air quality establishes a rate for whole building ventilation based on floor area and the number of occupants. When natural ventilation does not fulfill the entire established rate for whole building ventilation, mechanical ventilation is installed. In Wisconsin, the most common approach is exhaust-only ventilation. Local exhaust requirements may also be met by increasing the flow rate of installed whole building ventilation.

Follow these instructions for the installation of whole building exhaust ventilation:

1. Install fans in bathrooms or kitchens when practical to reduce overall flow rate when following alternate compliance for local exhaust requirements.

2. In line exhaust fans may be installed in a remote location such as the attic or basement. Ducting can be installed to one or two intake locations and then terminated to the outdoors. One option is to use existing ceiling exhaust as an intake location after removing fan assembly from housing. This option avoids cutting new holes in ceilings.
3. Install fans with built in controls or install separate control to allow for the adjusting of the flow rate and frequency of operation as needed. Label all controls.
4. Install service or shut off switch if not an integral part of control.
5. Measure flow rate of installed exhaust ventilation and record on Diagnostic Workbook. Record the highest flow rate in the exhaust fan section. Record the continuous or intermittent rate in the ventilation section.
6. Adjust the controls to provide the required flow rate at a continuous rate. Adjust controls for frequency of operation when operating intermittently. Intermittent operation should occur at least once in every three hour time period. The Diagnostic Workbook will assist installers in setting operational controls.
7. Calculate intermittent operation using this formula, required flow rate/measured flow rate x 60. The result is the number of minutes per hour that the ventilation should operate.

5.8.5 Exhaust Fan Ducting

Connect exhaust fan ducting to the outdoors and not to an attic, crawl space, or garage, where moisture and pollutants can accumulate. Duct exhaust fans to the outdoors as follows:

1. Use flexible or rigid ducting material.
2. Ensure that a backdraft damper is present. The damper may be part of the termination hood, it may be integrated into the fan unit, or it may be installed separately in the exhaust duct.
3. Where practical begin the ducting run by connecting a 1- to 2-foot section of rigid duct to the fan’s exhaust port, in order to improve airflow.
4. Avoid installing elbows at 90-degree angles — this can reduce airflow. Instead, install elbows at as gradual and smooth of an angle as is reasonable.
5. Make duct runs as short as is practical. Avoid long duct runs, especially where they are above the insulation or running horizontally.
6. Attach the ducting material to the fan’s exhaust port and to the termination hood.
7. Seal all joints in the exhaust-ducting run including at the fan and termination.

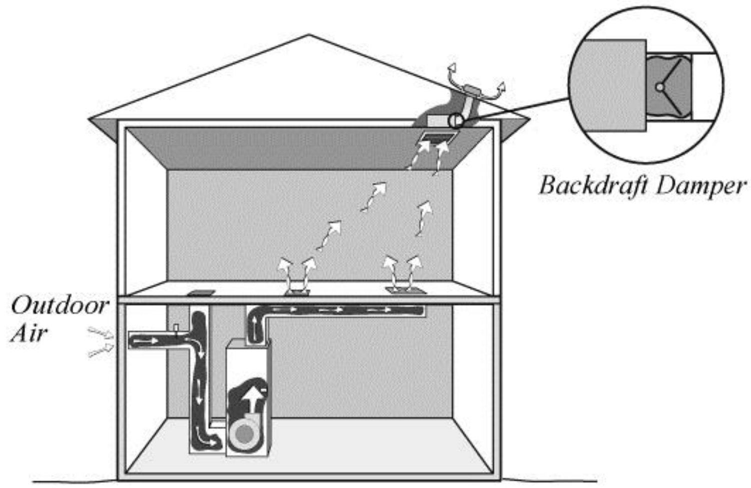
8. Insulate the ducting to a minimum of R-6 in unheated spaces. Ensure that the insulation is secure and provides continuous coverage.
9. In multi-family housing, for continuous ventilation, multiple exhaust fans may be combined into a “collector box” and exhausted with an appropriately sized termination hood.
10. Install termination hoods to the outdoors and not to a buffer zone, such as an attic, crawl space, or garage, where moisture and pollutants can collect.
11. Install the top half of roof caps underneath the shingles, in order to prevent rainwater from leaking into the attic. Use galvanized or stainless-steel fasteners, and use roofing cement to seal any leakage points.

5.8.6 Supply Ventilation Systems

Supply ventilation systems introduce fresh air into the home, and don’t include heat recovery. They are usually installed in conjunction with forced-air heating or cooling systems. They incur an energy penalty as unconditioned air is brought into the home. It is critical with this, and any other installation utilizing the forced air system, to follow the manufacturer’s requirements for mixed air temperature and the location of the fresh air insert. Failure to do so could crack the heat exchanger and void the heating system warranty. The temperature of the air should never be below 60° F for continuous air or 55° F intermittent air. Additionally, since this modification could result in cooler air temperatures, the customer must be understand and agree to this installation. Simple supply systems are difficult to balance effectively, especially in well-sealed homes. Central balanced ventilation systems are often a better choice considering overall efficiency and the need to balance house pressures.

The most common type of supply-only ventilation includes an outdoor air duct connected to the main return of a central forced-air heating or cooling system. The HVAC system’s fan draws outdoor air into the plenum, delivering ventilation air to the home along with heated or cooled air. No ventilation air is supplied unless heating or cooling is needed.

The fresh air duct should have a balancing damper installed so the airflow can be adjusted during the initial installation. A motorized damper is sometimes installed to close the outdoor air duct when ventilation air is not needed.



Supply air system: Fresh air is ducted to the furnace return plenum. The air handler draws air into the home. Some systems include an electrical interlock with exhaust fans.

Supply ventilation systems pressurize the home, forcing indoor air out through openings in the shell. This may keep outdoor pollutants, such as carbon monoxide from vehicles and lawn chemicals, out of the home, as long as the fresh air intake draws air from a clean location.

Pressurization can force indoor moisture into the walls. This can create condensation in building cavities during cold weather. Moderate levels of pressurization aren't usually a concern, though, if indoor humidity is kept within below 50%.

Supply systems that introduce air to the HVAC system can be configured to provide fresh air when neither heating nor cooling systems are operating. In this mode, the HVAC fan can circulate ventilation air only. This method is most efficient when a variable speed HVAC fan allows the slower airflow required for ventilation-only operation. Single-speed HVAC fans move too much air and consume too much electrical power for efficient continuous operation.

5.8.7 Balanced Ventilation Systems

Balanced ventilation systems provide measured fresh air via planned pathways. Of all the ventilation schemes, they do the best job of controlling pollutants in the home. (Note: Wisconsin Uniform Dwelling Code does allow ventilation to be balanced through the use of unplanned pathways when no atmospheric combustion appliances are located in the dwelling. Make-up is required when the combustion appliance zone is excessively pressurized or depressurized. For weatherization purposes use the Building Depressurization Guidelines to deter excessive depressurization.) *See Table 5-6* in Section 5.5.2.

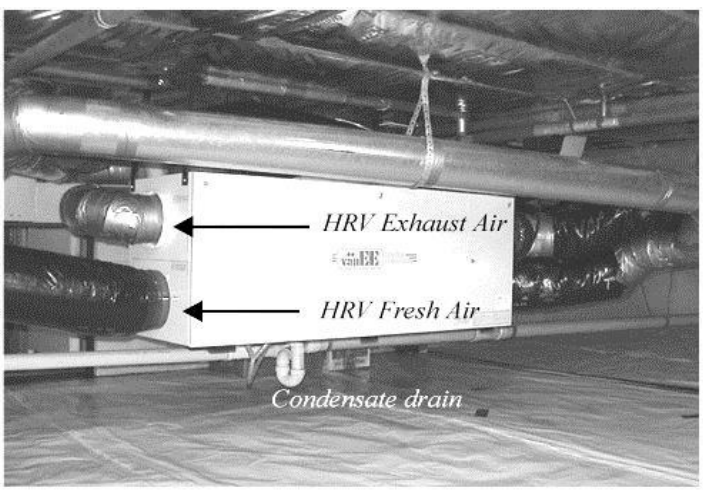
Designed balanced systems move equal amounts of air into and out of the home. Most balanced systems incorporate heat recovery ventilators that reclaim some of the heat and/or moisture from the exhaust air stream. Simple mixing boxes are occasionally used to temper incoming air by mixing it with exhaust air, but their cost approaches that of heat recovery ventilators, and they incur an energy penalty as conditioned air is lost to the outdoors.

Balanced systems, when operating properly, reduce many of the safety problems and moisture-induced building damage that is possible with unbalanced ventilation. Balanced systems are not trouble-free, however. Proper design, installation, and maintenance are required for effective operation.

These complicated systems can improve the safety and comfort of home, but a high standard of care is needed to assure that they operate properly. Testing and commissioning is vital during both the initial installation and periodic service calls.

Variation 1: Fully Ducted Balanced Systems

The most effective central ventilation systems include dedicated ductwork for both supply and exhaust air. All the ducting leads to a central ventilator which includes a HRV core to reclaim heat.



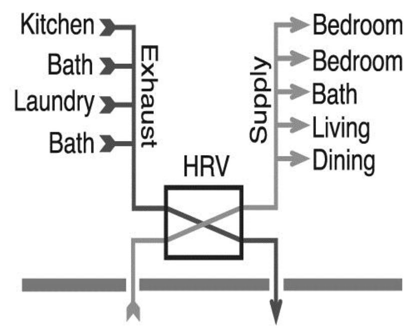
Fully-ducted heat recovery ventilator: Matched exhaust and supply fans provide balanced airflow. Dedicated exhaust ducting collects pollutants from bathrooms and kitchen. Supply ducting carries fresh air to bedrooms and central living areas. A heat-recovery core reduces energy loss from exhausted air.

Fully ducted systems are installed independently of other forced-air ducting. This gives the designer a high level of control over airflow and house pressure. They are most easily installed in new construction and are more difficult to install during weatherization.

High quality ductwork is a critical component of successful ventilation systems. Ducts should be sized large enough to minimize static pressure and reduce noise, and hard metal ducting used wherever possible. All seams and joints should be sealed using mastic or metallic tapes. Exhaust grilles should be installed near the sources of contaminants in bathrooms, kitchens, or other areas where other pollutant-producing activities take place.

Variation 2: Ducted-Exhaust Balanced Systems

Ducted-exhaust systems are connected to central forced-air systems. Dedicated ducting collects pollutants from bathrooms and kitchens. The exhaust air passes through a central HRV before being exhausted to the outdoors. Fresh air is brought in through the HRV, and is introduced to the forced-air system at either the supply or return plenum. Always follow the manufacturer's requirements for mixed air temperature, the location of the fresh air insert, and minimum return air temperature.



Fully-ducted central ventilator: Fully ducted systems do the best job of collecting pollutants. They are installed independently of heating and cooling systems, and work well in homes with hydronic or electric baseboard heat where no ducting is installed.

The airflow should be balanced in ducted-exhaust systems so house pressures remain close to neutral. In practice this is harder to achieve than in fully-ducted systems because of the influence of the forced-air blower. With typical airflows of 50-200 CFM, central ventilators are easily overwhelmed by the 500-1500 CFM airflows of forced-air systems. A high level of care is needed during design, installation, and commissioning of ducted-exhaust ventilation systems to achieve proper airflows and to achieve reliably balanced house pressures.

Variation 3: Simplified Balanced Systems

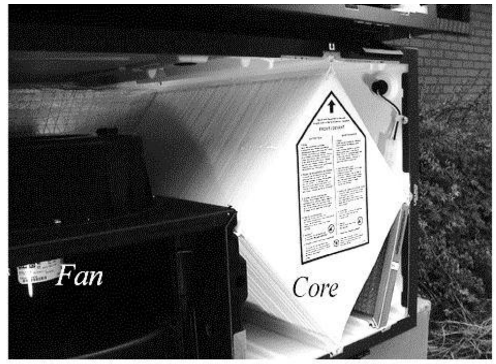
Simplified, or volume ventilation, systems are connected to central forced-air heating or cooling systems. This is the least-favored ducting option.

Simplified systems draw exhaust air from the forced-air return air plenum. This air passes through the central ventilator that includes an HRV. Most of the exhaust airstream's heat is transferred to supply airstream, and fresh air is re-introduced to the forced-air return ducting. Always follow the manufacturer's recommendation for interlocking the air handler with the fresh air inlet. This system requires the active involvement of the customer, as system failure will result if maintenance requirements are not followed.

5.8.8 Heat Recovery Ventilators

Heat recovery ventilators (HRVs) are often installed in conjunction with balanced whole-house ventilation systems. The HRV core is usually a flat-plate aluminum or polyethylene air-to-air heat exchanger in which the supply and exhaust airstreams pass one another and exchange heat through the flat plates.

Polyethylene HRV core: This flat-plate counterflow heat exchanger slides out for cleaning.



5.8.9 Ventilation Control Strategies

Controls provide a critical opportunity for fine-tuning during ventilation systems. Don't short-change this important component. Controls let the installer and customers choose when the system runs and how much air it moves.

Controls also provide an opportunity to adjust the system performance over time. Customers should be advised that a periodic review of the control scheme should be performed, perhaps during service visits, to assure that the system is providing sufficient fresh air for occupants and acceptable moisture control for the building.

Locate the controls in a representative location on a main floor interior wall, and about 60 inches above the floor. Don't install them on an exterior wall, in a drafty location, or in direct sunlight.

Manual Control

Simple on/off manual controls allow occupants to ventilate as needed. These are often used for exhaust fans in bathrooms and kitchens. Their effectiveness relies on the user's perception of air quality.

Manual override control: A central heat recovery ventilator, normally operating at low speed, is boosted to high speed by this push-button countdown timer.

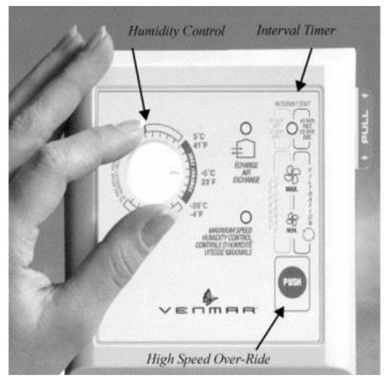
Manual controls sometimes include count-down or time-delay timers that are activated by occupants and run for a specific period of time. In non-owner occupied homes or other situations where occupant understanding and cooperation is unlikely, fan-delay timers can be run in conjunction with bathroom lights to give a set period of ventilation whenever the bathroom lights are used.

Humidity Control

De-humidistats operate equipment based upon indoor humidity levels. They are used with either simple exhaust fans or central ventilation equipment. De-humidistats can be set for a range of humidity levels, and have the advantage of automatic operation that doesn't require much occupant management. They should be set to keep indoor humidity low enough to prevent indoor condensation in the winter. This will vary from 30–50% rh, depending upon the outdoor temperature, effectiveness of windows and insulation, and other factors.

Combination Controls

Central ventilation systems are often operated by a combination of manual and automatic controls. The most common strategy utilizes a multi-speed fan that runs on low or medium speed to provide continuous ventilation. Override switches in the kitchen and bathrooms activate high-speed operation to provide intermittent high-speed operation during polluting activities such as cooking, bathing, or cleaning. The total airflow requirement specified by ventilation standards refers to this high-speed operation.



Central combustion control: The system can be controlled by humidity, time interval, or manually.

Timers allow the low-speed operation to be set for variable intervals such as 20 minutes on/40 minutes off per hour, 30 on/30 off, or whatever total ventilation time is needed. This adjustable interval provides an effective method of matching the ventilation capacity to the occupants' needs.

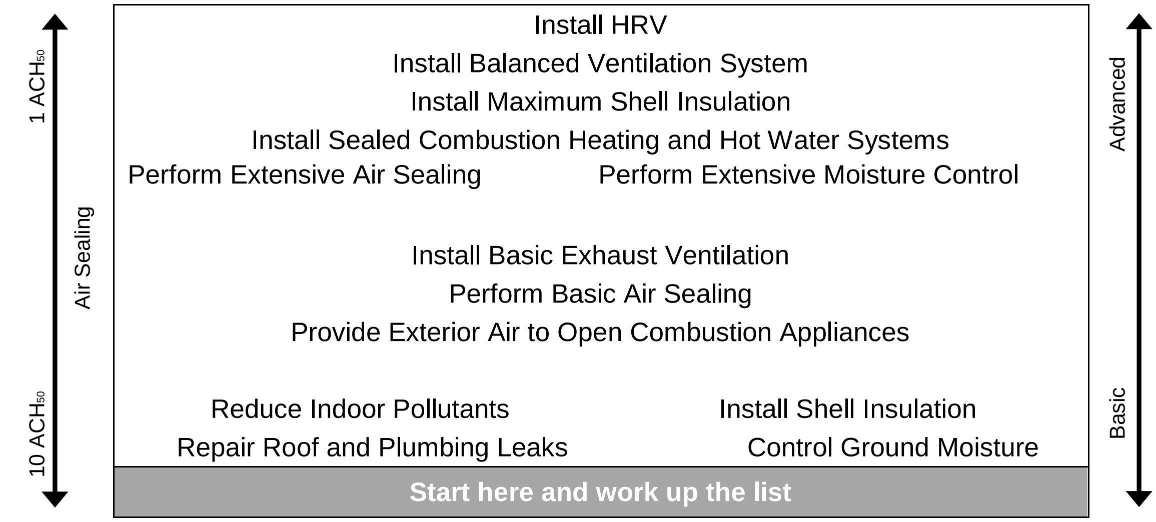
5.8.10 Priorities for Existing Homes

There are some advantages to designing ventilation systems for existing homes. First, the home provides an observable history from which to work. Stained ceilings, peeling paint, and mildewed attic framing all tell the story of how a building operates. The homeowner, too, may identify problems that are not immediately apparent, such as periodic back-drafting of combustion appliances. And the existing home has already aged, allowing lumber to dry and modern materials to out-gas, reducing the pollutant load on the ventilation system.

First, identify any major sources of moisture and other pollutants, and remove them or seal them away from the house. No ventilation system can effectively handle excess amounts of any pollutants.

Complete shell measures to assure reliable pressure and thermal boundaries. The heating, cooling, and ventilation systems depend on these measures to operate effectively.

Hierarchy of housing needs: Keep the entire structure in mind as you design and install mechanical systems.



The choice of ventilation equipment will depend upon the building's structure, airtightness, and mechanical systems. Many homes may require only exhaust fans. A blower door test, worst-case draft depressurization test, and an assessment of the home's existing ventilation will provide the information to determine the home's ventilation needs. *See Worst-Case Draft Protocol* in Section 5.5.2.

5.8.11 Installation Best Practices

A high level of quality control is needed to assure that ventilation systems work as intended. Properly designed and installed systems help create a healthy indoor environment and a long-lived building, while poorly executed systems can be ineffective or dangerous. Complex central heat-recovery ventilation systems require the most attention to design and installation.

Provide Ample Space for Equipment

Allow lots of room for ventilation equipment. Installers who are faced with under-sized mechanical rooms and poor provisions for ducting are forced to compromise the quality of their installations. Provide room for ductwork. A poor installation will occur when ducts are squeezed into framing cavities, access is difficult for sealing, and low-flow flex ducts are used to navigate tight spaces. You'll have excess noise when ventilators and ducts are forced against framing members with no acoustic isolation.

Final Inspection and Quality Assurance Standards

Acceptable installation for Health and Safety work shall meet the following requirements:

1. All Health and Safety measures were completed when appropriate to eliminate or reduce existing hazards or to eliminate or reduce hazards created as a result the installation of weatherization materials.
2. CO alarms are installed where required.
3. Smoke alarms are installed where required.
4. No conditions exist that warrant a deferral.

Ventilation for Indoor Air Quality

1. Whole building ventilation and local exhaust were installed as required.
2. Measured flow rate of whole building mechanical ventilation is between 90% and 150% of the ASHRAE 62.2 minimum calculated rate, as determined by the diagnostic workbook.
3. Installed whole building ventilation operates continually or on an intermittent basis with a customer shut-off switch.
4. Customer signed a “refusal of ventilation” if required.
5. Ventilation form fully completed and left with customer.